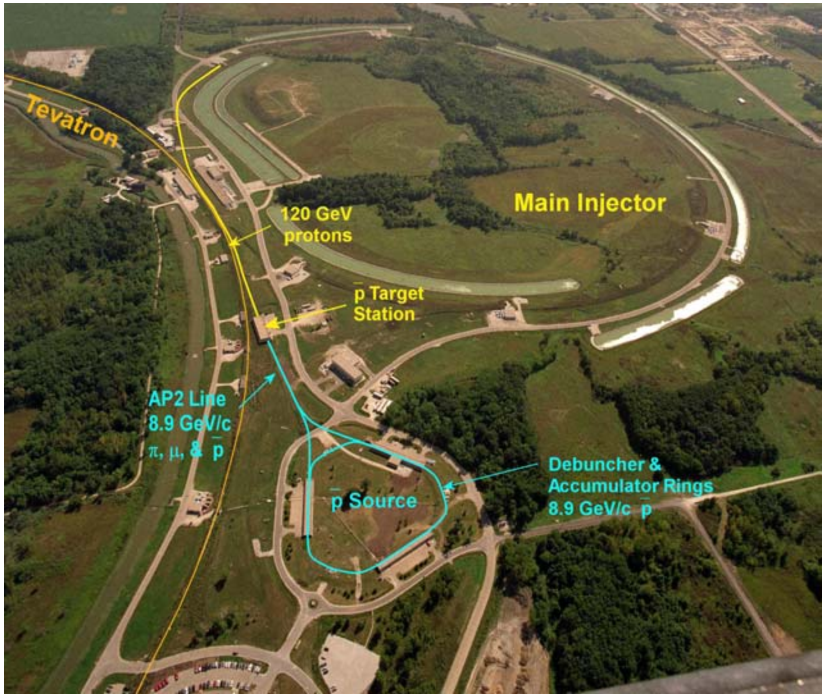
Run II Planning and Prospects beyond FY03

- Program of upgrade projects (MI-pbar-Tev)
  - Increase pbar production rate and stack size
  - Upgrade Tevatron for higher bunch intensities

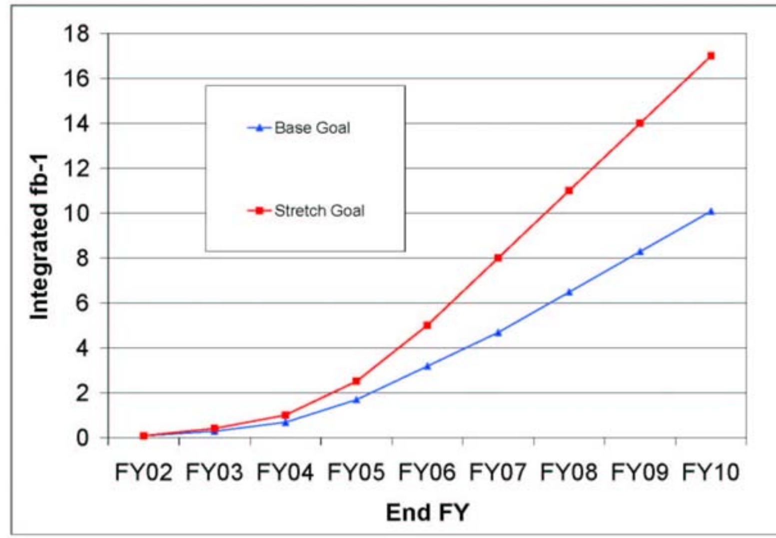


- Project Organization, Performance Goals, Scope, and Planning
- Technical Progress

Performance Goals

- Target: Base and stretch goals DOE Review Oct 02

End FY08:
Stretch Goal 11 fb^{-1}
Base Goal 6.5 fb^{-1}



- Performance goals, cost and schedule will be ~"bottom up"
- Plan is highly constrained:
  - Develop a phased approach for upgrades, while continuing to operate and increase luminosity
  - Limited shutdowns: <6 wks per summer, ~7 mth for experiment upgrades

Performance Target

	Typical Run Ib	Store 1953	Goal: FY03	Run II Target	
Peak Luminosity	1.6	3.7	6.6	33.0	$x10^{31} cm^{-2} sec^{-1}$
Integrated Luminosity	3.1	6[1]	12.0	70.0	pb^{-1}/wk
Store hours per week	84	86[1]	81[3]	98	
Interactions/crossing	2.5	1.0	1.7	8.5	
Pbar Bunches	6	36	36	36	
Form Factor	0.59	0.60	0.63	0.63	
Protons/bunch	23.0	16.3	24.0	27.0	$x10^{10}$
Pbars/bunch	5.6	2.5	3.1	13.5	$x10^{10}$
Total pbars	33.6	91.0	113.0	486.0	$x10^{10}$
Peak Pbar Prod. Rate	7.0	11.5[2]	18.0	45.0	$x10^{10}$/hr
Avg. Pbar Prod.Rate	4.2	6.9	11.0	40.0	$x10^{10}$/hr
Pbar Transmission Eff.	50	60	80	85	%
Stack Used	67	152	141[4]	572	$x10^{10}$
$\beta*$	35	35	35	35	cm
MI extraction Long.Emit.		3.5	2.5	2.5	eV s
Bunch Length (rms)	0.6	0.6	0.54	0.54	m
Proton Emittance (at coll)	23	19	20	20	π-mm-mrad
Pbar Emittance (at coll)	13	14	15	14	π-mm-mrad
Store Length	16	22	15	9	hr

(1) typical for Dec-Jan 03 (other numbers in this column are for store 1953)

(2) best stacking rate achieved $13.1x10^{10}$/hr

(3) excluding studies

(4) additional pBar stack used for RR commissioning

Compared to now
- x1.5 → Protons/bunch
- x5 → Pbars/bunch
- x3.5
- x5.7 → Avg. Pbar Prod.Rate

Project-Plan Organization

Project Manager: Jeff Spalding
Technical Coordination: Dave McGinnis

- **Protons on Target** — Ioanis Kourbanis
  - SlipStacking — Kiyomi Koba, Ralph Pasquinelli
  - Tgt&Sweeping — Jim Morgan
  - MI dynamics(1) — Bill Foster
- **Pbar Acceptance** — Steve Werkema
  - Li Lens — Jim Morgan
  - AP2&DB Acc — Keith Gollwitzer
- **Stacking & Cooling** — Dave McGinnis
  - Integration Task Force — Dave McGinnis, Alexey Bourov, Sergei Nagaitsev
  - Debuncher and Stacktail Cooling — Paul Derwent
  - RR Stoch Cooling(2) — Dan Broemmelsiek
  - e-Cooling — Sergei Nagaitsev
  - Rapid Transfers — Elvin Harms
- **Tev & Beam-Beam** — Vladimir Shiltsev
  - Task Force (3) — Valeri Lebedev, Tanaji Sen, Yuri Alexahin, John Johnston, Mike Syphers
  - Beam-beam Compensation — V Shiltsev
  - Lum Leveling — Mike Martens
  - Separation?

Notes
1) Includes issues associated with operating MI at high intensities for stacking and NuMI
2) RR commissioning is under FY03 project, represented here in the stacking and cooling scheme for the upgrade
3) Studies and simulations for Tevatron luminosity limitations are common with FY03 operational studies

Project Plan

1. Define and review the subproject scope
   - Done for pbar subprojects, underway for Tevatron
   - AAC Review Feb 03
2. Develop plan for phasing the upgrades
3. Prepare WBS and Resource Loaded Schedule
   - Director's Review May 03
4. Document Scope, Technical Plan and RLS → DOE June 1

- Also! – continue to make technical progress

Biggest issue: personnel shared with near-term Ops

Stacking and Cooling, and Tevatron Task Forces

→Develop parametric models for pbar production and Tevatron stores

1. Done: develop specs for pbar production, develop model for Tevatron (w/o beam-beam effects)
   →AAC Review

2. Next: develop model for pbar production, and scale of beam-beam effects in the Tevatron

   →Project phasing and scope for Tevatron upgrades
   →Dependence of luminosity performance vs parameters

Tevatron Stores

- Starting point:
  - 27E10 protons per bunch
  - pBar bunch intensity = 50% p bunch intensity
  - sustained pBar stacking rate = 40E10/hr
  - 2 hours shot setup (between stores)
  - on completion of the upgrades: 46 weeks per year HEP with 48 hours downtime per week

- Parametric model: achieves 3.3E32 peak, 3.2fb^{-1} pa

Tevatron Stores [Lebedev-AAC]

The model takes into account the major beam heating and particle loss mechanisms

- **Phenomena taken into account**

⇒ Interaction with residual gas

¨ Emittance growth due to electromagnetic scattering

¨ Particle loss due to nuclear and electromagnetic interaction

⇒ Particle interaction in IPs (proportional to the luminosity)

¨ Emittance growth due to electromagnetic scattering

¨ Particle loss due to nuclear and electromagnetic interaction

⇒ IBS

¨ Energy spread growth and emittance growth due to multiple scattering

⇒ Bunch lengthening due to RF noise

⇒ Particle loss from the bucket due to heating of longitudinal degree of freedom

- **Phenomena ignored in the model**

⇒ Beam-beam effects

⇒ Non-linearity of the lattice

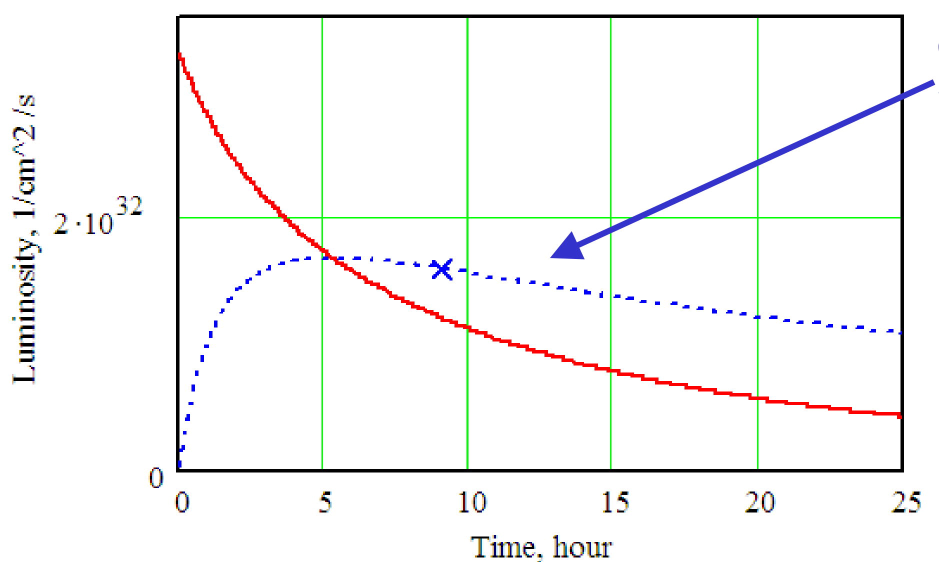
⇒ Diffusion amplification by coherent effects

- Thus, it can be considered as **the best-case scenario**

It describes well our best present stores

Tevatron Stores

- How robust is the integrated luminosity?
  - Leveling @2E32: lose ~12% (if required by experiments)
  - No recycling: lose ~10% (longer stores)
  - pbar=40%p: lose ~14% (shorter stores)
  - Average stacking = 30E10/hr: lose ~10% (longer stores)



average luminosity (incl shot setup) vs store length

Stacking and Cooling [McGinnis-AAC]

- Goals
  - Average Stacking Rate 40×10^{10} pbars/hour
  - Final Stack Size ~600×10^{10}
- Stacking process, system specifications and design issues
  - Accumulator optimized for rate:
    - Stacktail cooling 2-6 GHz (add 4-6 band)
    - Core cooling 4-8 GHz (no upgrade)
  - Rapid transfers
    - every 30 minutes in <1 min
  - Electron-cooling in Recycler
    - 22 eV-s/hr and 0.12 π mm mrad/hr per 100 mA electron current

Project Scope

Evaluate in terms of benefit (contribution to luminosity), cost, effort and technical risk

- Drop - position endorsed by AAC:
  - 132 nsec operation
  - recycling pbars from Tevatron
- Essential components:
  - Slip stacking
  - AP2+DB Acceptance
  - Stacktail Cooling
  - Rapid Transfers
  - Electron cooling
- Under consideration:
  - Active beam-beam compensation
  - Increased beam separation

AAC Review: Risks

From the AAC charge:
What are the primary accelerator physics and technology risks associated with this strategy?

1. "The highest risk which the committee identifies is the possibility that the TEVATRON falls short of the anticipated performance"
   - beam-beam interactions – increase helix separation and active compensation

2. electron cooling in the recycler ring – "allocating of resources and the overall priority does not seem to align with critical [status]"

3. upgrade of the antiproton production and cooling systems "very ambitious "
   - "plan is realistic and well developed but ultimate goals are challenging"
   - understand performance and limitations of the present system [benchmark]

Technical Progress

Slip Stacking [Kourbanis-AAC]

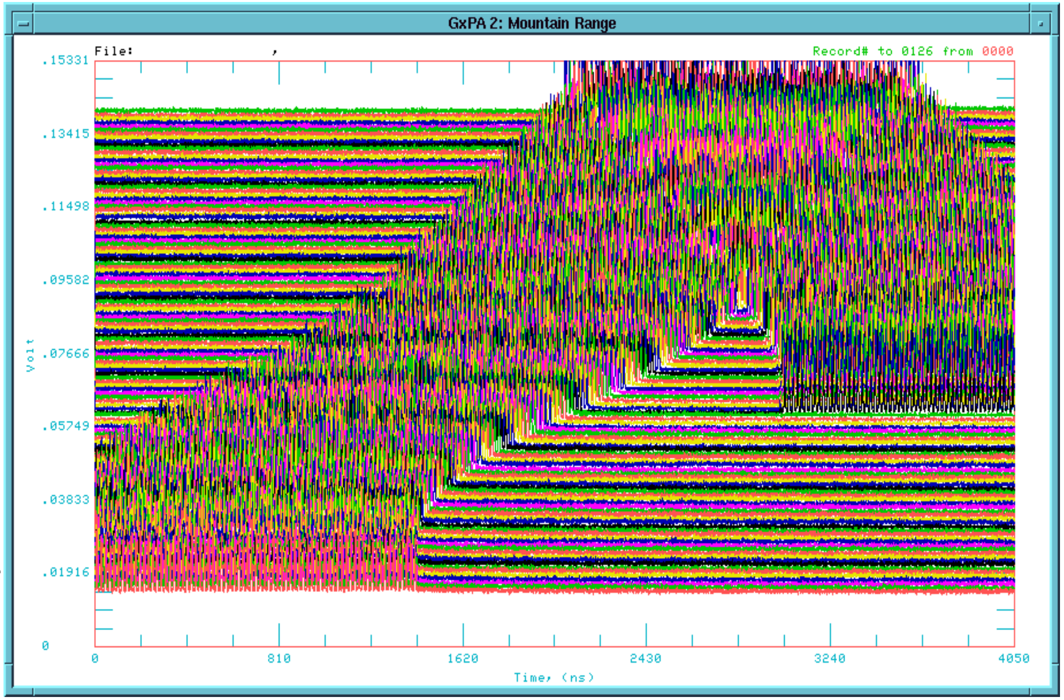
- Double the beam intensity on the pbar production target: Nominal 1E13 every 2 sec, parametric model uses 8E12

Test Program

- Successful at 0.8E12
- Accelerated to 120
- Compared to simulation

Beam-loading comp.

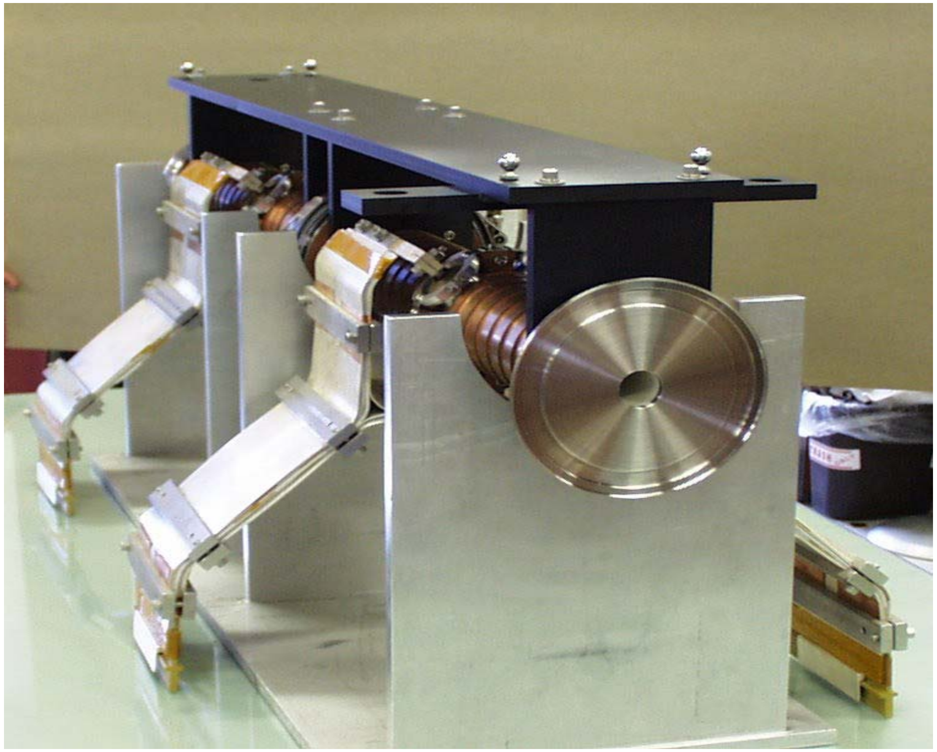
- Simulation and studies
- need 26db reduction
- Design: feed-back and feed-forward systems, RF amp tubes op in Class A, additional solid state amps
- Demo < summer → specs



Pbar Target and Sweeping [Kourbanis-AAC]

- Test Inconel alloys - more robust than existing nickel targets: 2 tested, 3 more installed for beam test

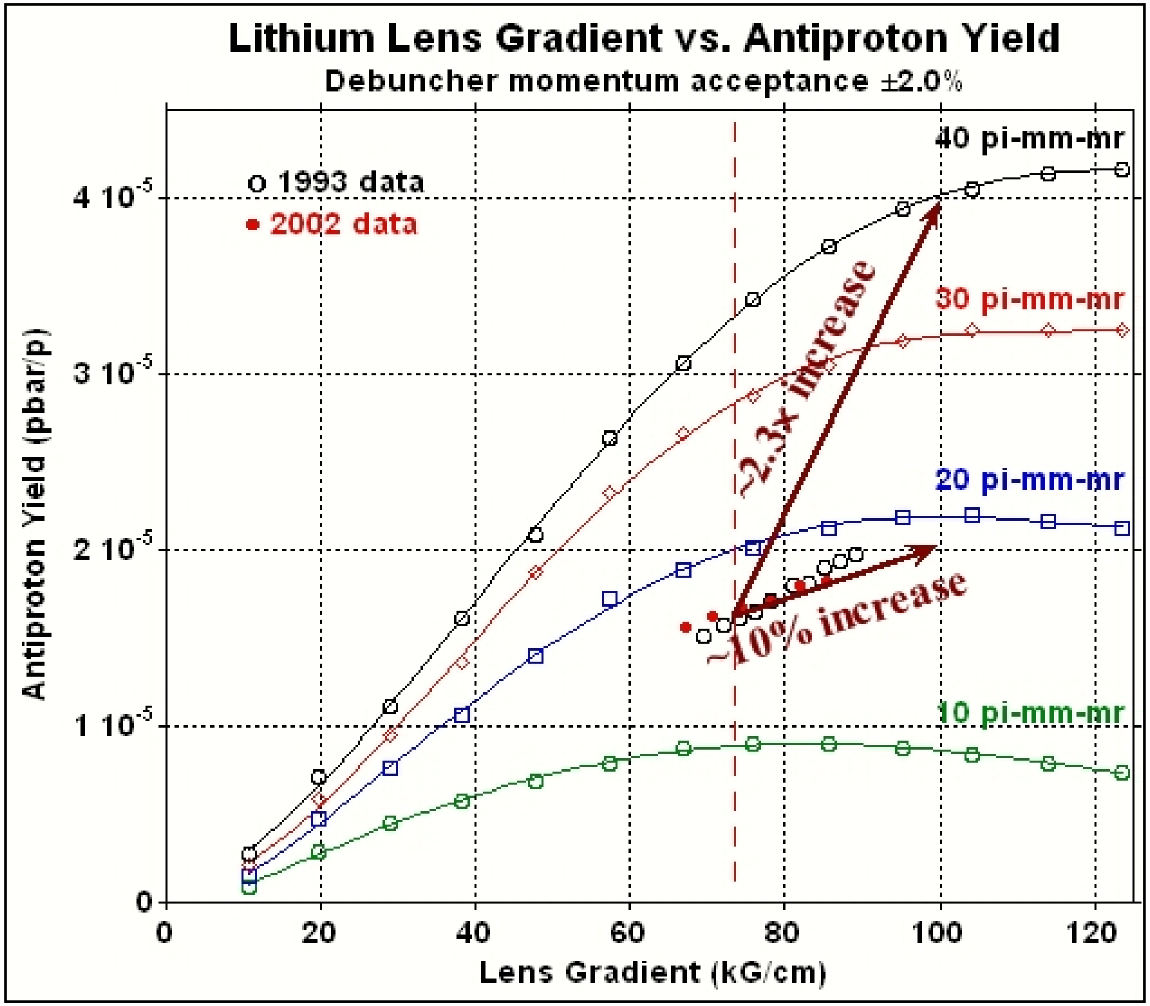
- Upstream target sweeping magnets have been installed and are ready to be tested. The downstream sweeping magnet is being completed and will be installed after testing the upstream magnets.



Pbar Acceptance [Werkema-AAC]

- Factor of 2.3 increase in $\bar{p}$ yield by raising the gradient to 1000 T/m and doubling the AP2/Debuncher Admittance to 40π-mm-mr

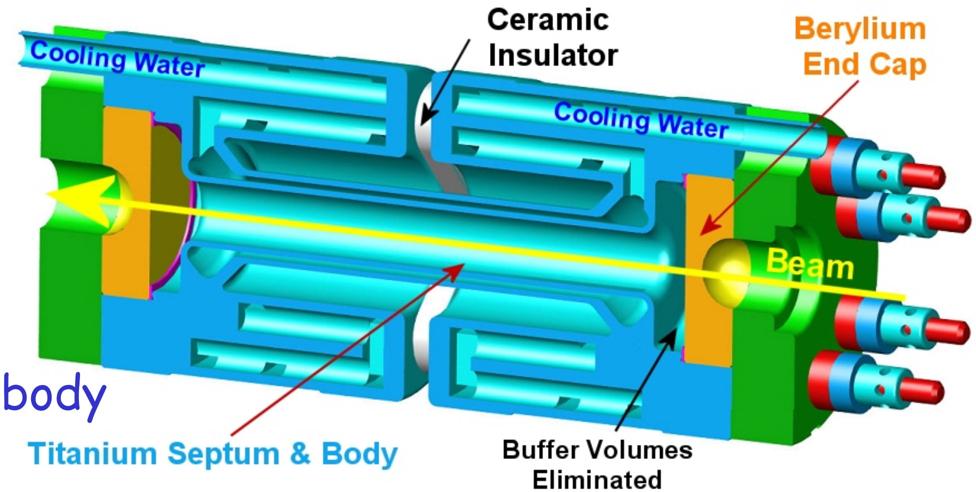
- Model assumes a factor 2.0



Lithium Lens [Werkema-AAC]

Improved assembly

- autopsies of failed lenses → septum cracks → improved control in assembly (preload for Li fill)
- two new lenses constructed



New design

- FEA and design of new lens
  - Diffusion bonded titanium body
  - Thicker septum
  - Elimination of buffer volumes
- Prototype#1 being fab'd and will be tested at high gradient
- Prototype#2 designed, will build after #1 tested

AP2 and Debuncher Acceptance [Werkema-AAC]

	Recent Measurements	Nom. Phys. Aperture
Horizontal (mm-mrad)	$20 \pm 1.5\ \pi$	$40\ \pi$
Vertical (π mm-mrad)	$12 \pm 1.5\ \pi$	$40\ \pi$
Momentum	±2.25%	±2.25%

parametric model uses 35π

- Identify and correct limiting apertures
  - Alignment
  - Orbit control
    - More AP2 trim dipoles
    - Debuncher moveable quad stands
  - Element redesign

- Document apertures (existing drawings, survey data, inspection) (FNAL:TD)
- Review optics and design of AP2→ Debuncher injection region (LBNL)

Stacktail Upgrade and Rapid Transfers [Derwent-AAC]

- Stacktail upgrade
  - Fully characterize present 2-4 GHz system, and benchmark simulation ← ongoing
  - Simulation with 4-6 GHz band added
    - Max stack rate 92E10/hr (a factor 2 headroom - spec is to sustain 40E10/hr)

- Rapid transfers
  - Currently transferring to RR ~daily – 1 hr gap in stacking
  - Aim for 0.5 hr with manual transfers
  - Automate transfers: mini shot setup → transfer on event
    - MI injection dampers, protocols for 120-8Gev ramps, improve power regulation

Electron Cooling [Nagaitsev-AAC]

- Completed Pelletron tests with U-bend
  - Meet specs except for recirculating stability:
    - @500mA spec<5min recovery per hour
    - actual~20sec per 4min @ design energy 4.3MeV, per 20 min @3.5MeV
    - →at spec, but trips too frequent
  - Additional 1MeV stage for Pelletron ordered to reduce field and improve operating stability
- Building beamline at wideband
- MI-31 construction notice to proceed this month
- Move to MI-31 in one year,add 6th stage to the Pelletron and commission with U-bend
- Install beamline in MI tunnel summer 04

Cooling section: nine 2m long solenoids supported from the tunnel ceiling

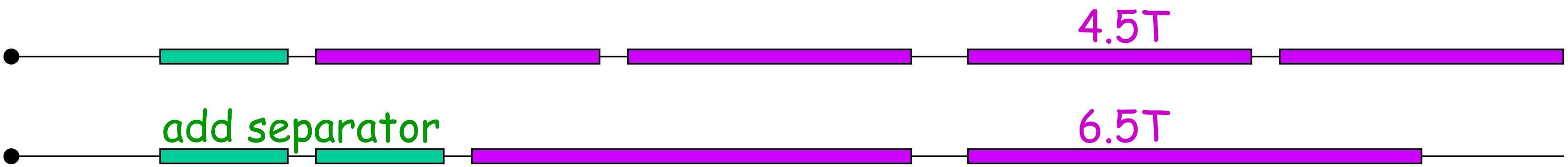
Active Beam-Beam Compensation [Shiltsev-AAC]

- TEL (Tevatron Electron Lens): bunch-by-bunch tune shift correction. Two needed.
- One TEL installed and used operationally to clean the abort gaps
- Gun and magnets upgraded in Jan shutdown
- Studies of proton tune shifts:
  - p lifetime at good WP ~160 hrs and tuneshift ~ 0.005
- Next:
  - Explore use of TEL for 150, ramp and squeeze
  - Study pbar tune shift and lifetime
- → decision on building second TEL

- Also investigating use of wire compensation (as proposed for LHC)

Increased Separation? [Shiltsev-AAC]

- Considering additional increase in helix separation to reduce the beam-beam effects
  - Parametric model and beam studies to develop concept for lattice and scale of improvement
  - Technical Division: conceptual estimate for new high field dipoles



- To install in 2006 shutdown, order superconductor summer 2003

- Goal is to review conceptual design by June (benefit, cost and schedule) and decide whether to include in scope

Summary

- Established Organization
- Developing project plan:
  - Parametric models:
    - define scope and phases for the upgrades
    - performance dependence on key parameters
  - Develop WBS and RLS
- Scope changes:
  - Drop 132 nsec and recycling
  - Investigate wire beam-beam compensation
  - Investigate increasing helix separation further
- Preparing documentation for DOE June 1

- And making significant technical progress on the subprojects

Project Scope

- 132 nsec operation
  - Original impetus for 132 nsec operation was to reduce the number of interactions /crossing for the experiments – this now appears manageable @396 (see below "luminosity leveling")
  - 132 requires a crossing-angle → ~40% red. in luminosity
  - Total protons x3 → concern about long range beam-beam interactions and instabilities
  - Would require large study and simulation effort
  - Significant work on hardware (separators, RF cavities… and instrumentation)

- pbar recycling
  - Historically ~30% of stores end prematurely
  - P. model: ~75% pbar left, 70% acceptance to RR

  } 37% pBars return to RR
  - Recoup with longer stores → lose ~10% in integrated luminosity
  - Biggest issue is the timely removal of protons (without risk to experiments or quenching), followed by pbar deceleration